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For Municipalities

Saving Energy in Street Lighting

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Introduction

As electric power costs rise, street lighting systems are accounting for a greater and greater share of the municipal budget. Recent technological advances have produced sodium lighting systems which can reduce power needs by more than 50%, and improve illumination levels at the same time. Yet the street lighting in most municipalities today is inefficient, outdated and expensive to maintain.

Improving the energy efficiency of street lighting results in dollar savings in direct proportion to the reduction in electrical load. And these savings can be considerable. Using 1978 figures, Ontario Hydro estimates that conversion of existing street lighting to sodium lighting systems would reduce connected load and electrical energy use for street lighting by more than 60% annually in Ontario.

Obviously, sodium lighting now offers municipalities a serious alternative to their street lighting systems. Other types of outdoor lighting (e.g. floodlighting of buildings, parking lots, playfields and recreational areas) are also good candidates for the more efficient sodium sources.

As with many new technologies, however, questions arise about actual performance and suitability. The safety, technical reliability and public acceptability of sodium lighting remain serious considerations for interested municipalities. And assessing the cost effectiveness of the sodium systems means weighing savings on electricity and maintenance against higher installation costs, particularly where still serviceable units are to be replaced.

It is now agreed that sodium lighting is the most efficient lighting source available today, and that where new installations are being considered there is no economic alternative. Where the question is whether or not to replace existing street lighting, however, only a careful review of a municipality's existing system can reveal whether conversion will be cost effective.

This section sets out factors to consider when undertaking this review, discusses alternative light sources and summarizes their relative effectiveness.

1- Assessing Illumination Requirements

It is important to remember that street lighting exists for very fundamental reasons: to facilitate traffic flow, to prevent accidents, and to deter crime and vandalism. Visibility requirements are therefore the most critical factor in designing or converting any street lighting system. Aesthetics may also be an important consideration.

To identify what visibility levels are necessary, a number of factors must be examined. First, the type of road to be lit dictates minimum levels of illumination, reflection and uniformity, termed photometric design criteria. Secondly, the effect of various road and traffic characteristics must be assessed. Called warranting conditions, these factors include road location, traffic volume, speed and capacity, level of service, history of traffic accidents, road geometry and any abnormal conditions such as persistent fog. To aid in the decision-making process, these warrants have been set out with specific figures which, although arbitrary, are based on many years' experience*. Finally, for collector and local roads, these warranting conditions are analyzed together with additional factors such as pedestrian traffic, location of commercial buildings, schools, residential areas, and so on.

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* Geometric Design Manual, Roads & Transportation Association of Canada, Ottawa, 1976

The result of this analysis is an optimal lighting design providing the required level of visibility for traffic safety. Alternative light sources, pole heights and pole spacing can then be considered to find the most efficient system for achieving the required lighting design levels.

2- Selecting an Energy Efficient System

Obviously the amount of electrical energy consumed by the light source selected, and efficiency in converting energy into illumination, is of prime importance. Yet other aspects of the lighting system also affect the amount of illumination made available - the light distribution characteristics of the luminaire, or light fixture, the height at which the lamp is mounted, its position and spacing, and the reflectance characteristics of the pavement.

This last item, road surface reflectance or luminance, can mean energy savings through the use of brightening agents to improve the reflective quality of pavement. In urban areas, however, factors like street parking and fallen leaves generally make surface reflectance too unpredictable to include in the calculation.

Alternative lighting systems - the options

Table 1 shows the overall advantages of sodium lighting, in terms of efficiency and lamp life. It also indicates that trade-offs may be called for in terms of colour quality.

Incandescent street lighting is still very common in many communities. It is the least energy efficient of all available light sources and is no longer considered an economical alternative for new street lighting systems due to high levels of energy consumption and high maintenance costs.

Although more efficient than the incandescent, the fluorescent street light luminaire is also uneconomic for new systems. The luminaires, or fixtures, are large, long and heavy which creates high installation, maintenance and storage inventory costs. The light source is also long, making light output difficult to control.

Mercury vapour streetlights became increasingly popular in the 50's because of their long lamp life and promise of lower maintenance costs in comparison with incandescent systems.

Metal halide luminaires are used primarily for floodlighting playfields and other such areas. They offer high efficiency and excellent colour rendition, but are not commonly used for street lights because of their lower life expectancy when compared with mercury vapour sources.

Low pressure sodium (LPS) is the most energy efficient of all lamp options. Poor colour quality, however, may make low pressure sodium systems unacceptable for some applications (e.g. downtown commercial/ pedestrian developments.) LPS is a monochromatic source of orange colour, and illuminated colours tend to appear as shades of grey.

TABLE 1
Light Source Characteristics

lamp type	efficiency[1] lm/W	lamp life[2] hours	colour quality
incandescent	15-20	2500	very good
fluorescent	40-60	9000-20000	good
clear mercury	40-50	24000	poor
colour corr. mercury	40-50	24000	fair
metal halide	65-90	7500-15000	good
low pressure sodium	90-160	18000	very poor
high pressure sodium	60-110	24000	fair

Source: Ontario Hydro

1 Wattage of ballast included.
2 Life length is based on 50% mortality, 10 hours per start.

In addition the LPS lamp, like the fluorescent, is large, and utilizing light output efficiently is difficult. Light spillage can therefore be a problem. A look at the total system in fact suggests that the efficiency of LPS and HPS units are similar.

Where colour differentiation is not important, or where light spillage is less critical, LPS lighting systems are an attractive option: they are exceptionally efficient; and they are the only light source which maintains a relatively constant lumen output over the life of the lamp.

High pressure sodium street lights (HPS) provide the best all-round source for street lighting: although rated slightly less efficient than LPS in converting energy to light, they give acceptable colour rendition and as "point sources" provide light which can be precisely controlled. They are also long-lived, with a lamp life equivalent to mercury vapour, and this means low maintenance and inventory costs. Finally, they are considered aesthetically pleasing, lending themselves to normal and decorative styling.

Because of the brightness of the HPS, lamp glare can sometimes be a problem. In most cases, this can be alleviated by mounting luminaires at the proper height.

Like all light sources, HPS lamps are not as efficient at smaller wattages. Thus, although HPS does produce four to five times as much light as incandescent for each unit of energy consumed, this ratio holds true only for larger units.

Some municipalities have attempted to avoid small units by installing higher wattage lamps and fewer poles. Care must be taken to avoid light pollution problems, however, and to ensure that design criteria are met.

3- A Test Case

One recent demonstration project provides interesting data on the comparative advantages of various lighting systems - comparing low and high pressure sodium with incandescent and fluorescent sources in selected communities. Undertaken by Ontario Hydro and the Ontario Ministry of Transportation and Communications, the project was designed to examine whether upgrading existing (and inefficient) lighting systems is economically justified, and if these changes are acceptable to the public.

Two Ontario cities, Belleville and Woodstock, participated in the project. In Woodstock, one collector and two residential streets were selected, all of which were lit with incandescent lighting. Original lighting for the four residential streets in Belleville was fluorescent.

In all cases the changeovers were based on certain assumptions:

- light output with the replacement equipment would meet old equipment performance, but would not exceed recommended values for the particular roadway classification;
- no poles or bracket arms would be changed, and the mounting height (and spacing) would remain the same;
- all new luminaires would be fitted with individual photocells.

In summing up its findings, Ontario Hydro concluded that life-cycle cost analysis does not warrant a changeover in Belleville (from fluorescent) yet more than justifies a complete changeover to high pressure sodium in Woodstock (from incandescent). In addition, it became apparent that performance of the new vertical-burning units did not significantly increase the levels of average illuminance. A similar project in Etobicoke, however, indicated that a horizontal burning unit of the same wattage will produce approximately twice the average illuminance of a vertical-burning unit* but with increased uniformity levels.

Project findings were particularly revealing in terms of efficiency, cost effectiveness and public acceptability.

* Replacing Incandescent Lamps with Energy-Saving Lamp/Luminaire Systems in Residential Street Lighting - A Case Study, C. Blamey, System Research and Development Division, Ontario Ministry of Transportation and Communications, Downsview, Ontario.

TABLE 2

Energy Savings From Changes To Street Lighting In Belleville and Woodstock

	Old Lighting	New Lighting	Energy Savings	Increase in Average Foot Candles	Change in Uniformity
Fluorescent (Belleville)					
Linton Park	2 x 60 W	70 W HPS (vertical)	45%	.22 - .23*	6:1 - 4:1
Lambert	"	55 W LPS	50%	.20 - .33	5:1 - 3:1
Keller E.	"	100 W HPS (horizontal)	25%	.29 - .88*	6:1 - 9:1
Keller W.	"	90 W LPS	25%	.21 - .48	9:1 - 10.1
Incandescent (Woodstock)					
Springbank	500 W	100 W HPS (horizontal)	74%	.21 - .76*	2:1 - 3:1
Vanier Nesbitt	300 W	70 W HPS (vertical)	68%	.08 - .17*	11:1 - 4:1
Bay	300 W	70 W HPS (conversion kit)	68%	.11 - .15*	6:1 - 3:1

Source: Energy Conservation Demonstration Street Lighting Projects, Woodstock and Belleville, Ontario Hydro, Toronto 1978.

* Initially. The values of illuminance for HPS units decline over time.

Efficiency

Results from both Belleville and Woodstock show that average illuminance values can be increased by changing to sodium sources, with energy savings from 25 to 74% See Table 2.

Cost effectiveness

Although conversion to sodium sources is unquestionably energy-conserving, economics alone will not justify such conversion in every case. On the plus side are substantial savings in energy costs and maintenance - on the average, sodium lamps require replacement every four years, compared to every six months for incandescent lamps and every two years for fluorescent lamps.

A secondary and potentially valuable advantage is the reduction in inventory space involved, and the savings in salaries from a reduced maintenance schedule.

On the other hand, a significant capital outlay can be involved, depending on existing lighting systems. A 10-year life-cycle cost analysis* of the conversions carried out in Belleville and Woodstock illustrates some of the variables. In Belleville, a comparison of fluorescent, 70W HPS and 55W LPS revealed that discounted costs for the new luminaires were $65,000 higher than for the original fluorescent over a 10-year life cycle ($90/unit).

In Woodstock, keeping the original incandescent system proved to be significantly more expensive over a 10-year life cycle than replacement with the new retrofit HPS units. Use of an HPS conversion kit, which retains the original housing, reduced costs by an additional $60,000 because of the lower capital outlay. On the Woodstock collector road savings with HPS units were even more striking: $10,000 in present day dollars ($180/unit) for only 56 units.

This analysis changes as electricity costs rise.

For each municipality, then, the kind of street lighting already installed is a major factor in deciding whether to introduce a conversion program. There are other considerations, however. Are existing poles well-positioned, or is new spacing required? Are new poles or brackets necessary? Can a conversion kit be used to adapt the incandescent or mercury vapour luminaire for an HPS lamp? All of these factors will influence the equation.

Among its options the municipality can choose to convert sections of its existing system or adopt a replacement policy, installing more efficient units as old lamps or luminaires fail. Where lamps or luminaires removed in a conversion program are still serviceable, they can be used to replace failed units in other areas.

Public acceptability

What did people think of their new street lighting? Results from Ontario Hydro's attitude survey were unanimously favourable to the new light sources. Most residents interviewed felt that all the original street lights were satisfactory, and in both communities rated the 100W HPS replacement lights equal to or better than those they replaced. LPS lamps were also satisfactory, perhaps because they so closely resembled the original fluorescent lamps in shape. The 70W HPS units got mixed reviews, however: reported satisfaction ranged from 92.1% in Woodstock (where they replaced incandescent) to 61.6% for the same lamps in Belleville (where they replaced fluorescent). Most new street lights are seen as making streets somewhat more narrow. With the exception of 100W HPS they were also thought to make streets slightly less safe.

Another survey was carried out after new 100W HPS street lighting was installed in the test streets in Etobicoke. Results indicate that residents were extremely pleased with their new lights.

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* This calculation assumed the following:

- capital outlay amortized over ten years at an interest rate of 10% per year.
- labour and materials costs for group and spot relamping increased by 8% per year.
- labour and materials costs increased by 40% to cover overhead charges.
- electricity charges increased by 8% per year.
- 4,300 lamp burning hours per year.
- annual total costs discounted to present value using a discount rate of 10%.

Approximately 85% stated that the new lighting was bright enough, compared to only 36% for the original incandescent. Only 1% considered the new lights too bright and the yellow hue was thought to be exceptionally easy on the eyes.

When it came to traffic safety, only 12% of respondents felt that it was difficult for drivers to see pedestrians at night with the new lights. This rose to 66% among residents in a control group drawn from incandescent-lit areas.

As for crime reduction, feelings of security did not change with the increase in illumination. However, in the control group, where there was no change in the lighting, there was a marked decrease in respondents' feelings of security once the new system had been installed in other parts of the city.

Only 100W HPS units were installed in Etobicoke. Results from the two projects seem to indicate that the public attitude to 100W HPS units is highly favourable whereas reaction to the smaller units is mixed, particularly when they replace fluorescent lights.

4- Other Factors

Safety

Proper illumination can have a significant effect on traffic safety. When the City of Toronto converted expressway lights on the William Allen Expressway from fluorescent to low pressure sodium in 1968, the result was a 35% reduction in night-time accidents on that same stretch of expressway over the next eighteen months. The two Ontario studies clearly show that a switch to sodium lamps increases average illumination levels, by as much as 300%. Where existing illumination levels require upgrading, therefore, sodium units offer an opportunity to improve lighting levels while reducing power costs.

The converse is that attempts to reduce energy consumption by reducing illumination levels could lead to decreased safety - a higher accident rate, vandalism and increased crime. Consequently any move to reduce lighting levels for conservation purposes should be weighed carefully. One experiment in Europe showed that a 30% increase in freeway accidents and an 11% increase in urban accidents occurred when illumination was removed.

Turning off every other light along a stretch of road is another alternative that is occasionally considered. This, however, would create a hardship for a driver passing through a continuous series of light and dark zones.

It can be claimed that reducing lighting levels much below design criteria is virtually the same as removing all lighting. The small amount of illumination which remains is not sufficient for safety purposes, and may give drivers a false sense of security. In fact, although energy is saved, the amount consumed is wasted since it does not provide the safety level required.

Appropriate lighting design

When sodium units are considered for outdoor lighting care must be taken to incorporate the advantages this technology offers, particularly when traffic-related criteria do not apply. A study of shopping centres in the Waterloo area of Ontario showed that of the three malls lit by HPS, only one was designed to take advantage of its efficiency: energy consumption figures were low and there were no problems of glare or excessive illumination. The other two malls used more energy than similar malls with mercury installations - the greater efficiency of HPS appeared as unnecessarily high lighting levels with accompanying problems of glare and light pollution.

5- In Conclusion

- All new street lighting installations should use the most efficient light source available (i.e. either low or high pressure sodium) to meet requirements.

- Municipalities with incandescent street lighting should consider converting their system to high pressure sodium units immediately.

- Where the existing system is mainly fluorescent municipalities should examine carefully the present and future cost effectiveness of converting to or spot replacement with a sodium lighting system.

Sources

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APPENDIX

Steps To Take In Reviewing Your Street Lighting System*

1. Examine the street lighting record.
2. Determine:
   - what % incandescent - ________ kw
   - what % mercury vapour - ________ kw
   - what % flourescent - ________ kw
   - Total Load - ________ kw
3. List various wattages of each lamp and beside it the equivalent retrofit lamp of equal (or more) lumen output.

   Attached is a form you might want to use.

   When you have completed the form, subtract column "J" from "E" for HPS kw savings or column "O" from "E" for LPS kw savings. Total them for each lamp type and compute the load and kwh reduction, multiply by the cost per kwh, and you will have the $ saving.
4. Contact your major lamp and luminaire representatives for free analyses of your system. Major Canadian suppliers of sodium systems are Canadian General Electric Company Ltd., Sylvania, Westinghouse Canada Limited and Philips Electronics Limited. Representatives from provincial utilities can also help you if requested.
5. Another avenue would be to write to your provincial department responsible for Transportation.

* Adapted with the permission of Ontario Hydro.

Street Lighting-Energy Potential For Your Municipality.

INCANDESCENT						RETROFIT LAMPS									
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
LAMP WATTS	BALLAST WATTS	TOTAL WATTS	ÉOF UNITS INSTALLED	kW LOAD	INITIAL LUMEN OUTPUT	HPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT	LPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT
TOTAL INCANDESCENT						TOTAL HPS					TOTAL LPS				

MERCURY VAPOUR						RETROFIT LAMPS									
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
LAMP WATTS	BALLAST WATTS	TOTAL WATTS	ÉOF UNITS INSTALLED	kW LOAD	INITIAL LUMEN OUTPUT	HPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT	LPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT
TOTAL MERCURY VAPOUR						TOTAL HPS					TOTAL LPS				

FLUORESCENT						RETROFIT LAMPS									
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
LAMP WATTS	BALLAST WATTS	TOTAL WATTS	ÉOF UNITS INSTALLED	kW LOAD	INITIAL LUMEN OUTPUT	HPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT	LPS LAMP WATTS	BALLAST WATTS	TOTAL WATTS	kW LOAD	INITIAL LUMEN OUTPUT
TOTAL FLUORESCENT						TOTAL HPS					TOTAL LPS				

Remember Multiply kW reduction by 4300 hours to get your energy savings.